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LABORATORY OBSERVATIONS ON PREDATION UPON ANOPHELINE LARVAE BY SOME ANISOPTERAN AND ZYGOPTERAN LARVAE IN BOLIVIA AND THE DURATION OF THEIR ULTIMATE INSTARS

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The results of laboratory observations on predation upon anopheline larvae by some anisopteran and zygopteran larvae are presented, and the duration of ultimate, penultimate and antepenultimate instars of *Acanthagrion peruvianum* and of ultimate instar of *Erythrodiplax connata fusca* are determined.

INTRODUCTION

It is well known that the larvae of Odonata are aquatic and predaceous, and will readily devour the larvae of mosquitos. However, papers dealing with quantitative analysis of predatory ability of larval odonates are rather scarce. AINO (1935) recorded the prey for the larva of the following taxa: 7-8 chironomid larvae per day for the last instar of *Sieboldius japonicus* Sel.; 8-10 tadpoles of 1.5-2.0 cm in length per day for the last instar of an aeshnine larva; 13-45 chironomid larvae or 11-32 culicid larvae per day for the last instar of *Orthetrum albistylum* Sel.; 9-17 culicid larvae per day for the last instar of *Sympetrum darwinianum* Sel., in other words approximately 1,000 culicid larvae for the entire period of larval life; about 10 chironomid larvae per day for the last instar of *Epiophlebia superstes* Sel.; 4-7 *Baëtis* sp. larvae per day for the last instar of *Calopteryx costalis* Sel.; 28-31 culicid larvae for the 4th, 20-29 for the 5th, 28-36 for the 6th, 35-44 for the 7th, 46-66 for the 8th and 47-93 for the 9th instar of *Lestes temporalis* Sel. with an estimate of more than 400 culicid larvae devoured during the 40-50 days of its larval life, including those killed but not eaten. He did not mention about the specific identity of the culicid larvae used for observation. LIEN & MATSUKI (1979) recorded the results of their laboratory observation on predation upon the larvae of *Aedes togoi* by the larvae of *Lyriothemis tricolor* Ris that breed in artificial containers in Taiwan. Their observations shows that the mean number of larvae devoured varies between 0.8 and 12.4 per day. The authors considered it to be one of the important natural enemies of artificial container breeders.

During our field evaluation of the efficacy of the products of *Bacillus thuringiensis* serotype H-14 against anopheline larvae carried out at the locality Chaco (elevation: 1,900 m), provincia Oropeza, departamento Chuquisaca in Bolivia, the authors felt that some anisopteran and zygopteran larvae play an important role in suppressing anopheline population in the area, and it was decided to carry out quantitative laboratory observation on their predation upon anopheline larvae. This paper is to record the results of the quantitative laboratory observation.

MATERIAL AND METHODS

Larval odonates were collected from the breeding places of *Anopheles pseudopunctipennis*, one of the two important vectors of malaria in Bolivia. In the Chaco area, the main breeding places of the mosquito are seepages, ditches with a dense covering of aquatic plants, and shallow springy pools on stream beds with or without filamentous green algae. All of such habitats were well exposed to the sun. The sites densely covered with aquatic plants are the places most preferred by the larvae of *Acanthagrion peruvianum* Leonard, 1977 and *Erythrodiplax connata fusca* (Ramb.). Larval odonates collected from such sites were brought back to an entomology laboratory in Cochabamba (elevation: 2,558 m) for observation.

Each larva was placed in a wide mouth glass bottle of 100 ml capacity, filled with about 30 ml of water. A stick of 15 cm in length was inserted to the bottles as foothold for the larval odonates. Five to 20 4th instar larvae of *An. pseudopunctipennis* from laboratory colonies were put into each bottle, and on the following day the number of larvae devoured was recorded, and the same number of mosquito larvae was replenished daily until adult emergence. During the period of observation, the room temperature fluctuated between 20 and 25° C each day, and the relative humidity varied between 30 and 50%.

RESULTS

Analysis of the results of observation as shown in Table I indicates that the mean number of larvae devoured daily by the five different taxa varies between 1.53±0.40 and 9.8. The mean number for the group with entire period of instar observed differs significantly from the group with partial period of instar observed as in the case of ultimate and penultime instars in *Acanthagrion peruvianum*, and ultimate instar in *Erythrodiplax connata fusca*. This phenomenon can be explained by the fact that in the later part of the ultimate instar fasting by the

Table I
Mean number of mosquito larvae devoured each day by larval odonates with 95% confidence interval

Odonate species	Instar*	Period of instar observed	Number used	Mean number of larvae devoured	Comparison of entire versus partial period of instar observed
Acanthagrion peruvianum	0	entire	27	2.83±0.23	P<0.001 significant
Acanthagrion peruvianum	0	partial	23	2.05±0.23	
Acanthagrion peruvianum	1	entire	9	2.99±0.29	P<0.001 significant
Acanthagrion peruvianum	1	partial	18	2.13±0.23	
Acanthagrion peruvianum	2	entire	3	2.17±0.83	P>0.05 not significant
Acanthagrion peruvianum	2	partial	6	2.00±0.32	
Acanthagrion peruvianum	3	partial	3	2.00±0.23	
Erythrodiplax connata fusca	0	entire	7	5.64±0.70	P<0.001 significant
Erythrodiplax connata fusca	0	partial	15	2.65±0.55	
Erythrodiplax connata fusca	1	partial	7	3.89±0.87	
Unidentified very small damselfly	0	partial	6	1.53±0.40	
Ischnura fluviatilis	0	partial	1	2.90	
Aeshna d. diffinis	0	partial	1	9.80	

* Instars are numbered in reverse order (0, ultimate; 1, penultimate; 2, antepenultimate; 3, anterior antepenultimate).

larvae for a few to several days was observed, while in the early part of the same instar no fasting was observed. With the larvae of *A. peruvianum*, the mean number of larvae devoured also varied in different instars. The voracity is proportional to the size of larval odonates, i.e. the larval odonates large in size devour more mosquito larvae than those smaller in size.

As shown in Table II, the mean number of mosquito larvae devoured by *A. peruvianum* varied significantly during the development as ultimate instar. Shortly before adult emergence the larvae were less active in voracity, the mean number being 0.95±0.27, while in the early part of the same instar, the larvae were more active in voracity, the mean number being 3.77±0.28. This phenomenon

Table II
Comparison of the numbers of mosquito larvae devoured daily among early, middle and late parts of respective instar

Odonate species	Instar*	Number used	Days of instar observed	Mean number of larvae devoured	Comparision of first part versus last part of instar observed
Acanthagrion peruvianum	0	27	first 5	3.77±0.28	$P<0.001$ very significant
Acanthagrion peruvianum	0	27	middle 4-9	3.57±0.32	
Acanthagrion peruvianum	0	27	last 5	0.92±0.27	
Acanthagrion peruvianum	1	9	first 3	3.07±0.50	$P>0.05$ not significant
Acanthagrion peruvianum	1	9	middle 1-5	3.16±0.36	
Acanthagrion peruvianum	1	9	last 3	2.55±0.27	
Acanthagrion peruvianum	2	3	first 2	1.33±0.65	$P>0.05$ not significant
Acanthagrion peruvianum	2	3	middle 2-5	2.68±0.80	
Acanthagrion peruvianum	2	3	last 2	2.50±1.13	
Erythrodiplax connata fusca	0	7	first 5	6.66±0.42	$P<0.001$ significant
Erythrodiplax connata fusca	0	7	middle 3-19	1.43±1.10	
Erythrodiplax connata fusca	0	7	last 5	1.86±1.10	

* As for Table I.

was mentioned in the foregoing paragraph. With the larvae of penultimate and antepenultimate instars, the activity of predation did not vary significantly among the early, middle and late parts of the same instar. With the ultimate instar of the larva of *E. connata fusca*, the same phenomenon was also observed.

As shown in Table III, with the materials from the Chaco area we were able to determine the duration in days of ultimate, penultimate and antepenultimate instars (14-19, 7-11 and 6-9 days respectively) for *A. peruvianum* and of the ultimate instar (13-29 days) for *E. connata fusca*.

DISCUSSION

Anopheline larvae are surface feeders and rest horizontally on the surface of water, therefore an efficient predator must have a habit of feeding near the surface of water. If the predator is a bottom feeder, then it would not constitute an efficient natural enemy of surface feeding anophelines. With aquatic plants as foothold, the larvae of *Acanthagrion peruvianum* and other odonate taxa occurring in the breeding places of *Anopheles pseudopunctipennis* can successfully and efficiently prey upon anopheline larvae. As shown in Table III the estimated numbers of mosquito larvae devoured during the entire period of respective instar are 43-53, 22-33 and 8-28 larvae respectively for ultimate, penultimate and antepenultimate instars of *A. peruvianum*, and 50-116 larvae for ultimate instar of *Erythrodiplax connata fusca*. Using these indices one can calculate the degree of contribution of the odonates in suppressing the populations of larval anophelines when the density of larval odonates in the area is investigated and determined.

Table III
Duration in days of different instars and estimated number of larvae devoured during the entire period of respective instar

Odonate Species	Instar*	Number used	Duration in days		Estimated number of larvae devoured for entire period of instar
			Range	Mean	
Acanthagrion peruvianum	0	27	14-19	16.9±0.4	43-53
Acanthagrion peruvianum	1	9	7-11	9.1±0.9	22-33
Acanthagrion peruvianum	2	3	6-9	7.7±1.7	8-28
Erythrodiplax connata fusca	0	7	13-29	22.1±4.6	50-116

* As for Table I.

Larvivorous fish can be used to control mosquito larvae successfully in some areas where aquatic plants are not dense, however in the habitats densely covered with aquatic plants, the predatory activity would be seriously prevented. In such case larval odonates no doubt contribute very much in reducing the size of anopheline population. Not only the larvae do so but also the adults. In the Chaco area, there exists a vast area of anopheline breeding, such as seepages, streams and shallow pools densely covered with aquatic plants where use of larvivorous fish is not feasible. In the field observation in the Chaco area, the density of larval odonates, especially that of *A. peruvianum* and *E. connata fusca*, was found to be extremely high in the months of March and April in 1985 when adult emergence took place very actively, while the density of the larval odonates dropped abruptly in the months of May and June of the same year when adult emergence took place much less actively (unpublished). In these months the adult densities of *An. pseudopunctipennis* determined by nocturnal captures in a tent with man as bait for 3 hours and half after sunset (1830-2200) were 147, 261, 568 and 449 females respectively for March, April, May and June (unpublished). The low anopheline density corresponds with the high odonate density, while the high anophline density corresponds with the low odonate density. This phenomenon strongly suggests a possible contribution of larval odonates in suppressing the larval anophelines in the area. Of course there are many other factors that may contribute to suppression of anopheline population other than predation by larval odonates.

At present it is not feasible to culture larval odonates for use in larval mosquito control in the field. However, the only thing that one can do is to protect natural population of larval odonates, by not using chemicals to control larval mosquitos. Application of chemical larvicides would adversely affect natural population of Odonata and other natural enemies of mosquitos. Once the natural population is destroyed it would be very difficult to restore to its original population size in a short period of time. Therefore it is more appropriate to recommend use of biological insecticides, such as products of *Bacillus thuringiensis* serotype H-14 which would not kill non-target animals, in such a place like Chaco.

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